SLOVAK UNIVERSITY OF TECHNOLOGY IN BRATISLAVA

FACULTY OF CHEMICAL AND FOOD TECHNOLOGY

INSTITUTE OF INFORMATION ENGINEERING, AUTOMATION AND MATHEMATICS

Theory of Automatic Control 3

Relay-Feedback-Based Auto-Tuning

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1 Identification

We had a process, which was the stable, 2nd order transfer function with time delay, i.e.

$$G(s) = \frac{Z}{T^2 s^2 + 2Ts + 1} e^{-Ds}$$

where *Z* is the system gain, *T* is the time constant and *D* is the time delay.

The first task was the identification of the process. We created MATLAB/Simulink scheme to run realy-feedback control. As you can see in the figure 1, the relay secured us regular oscillations of the output value around the setpoint.

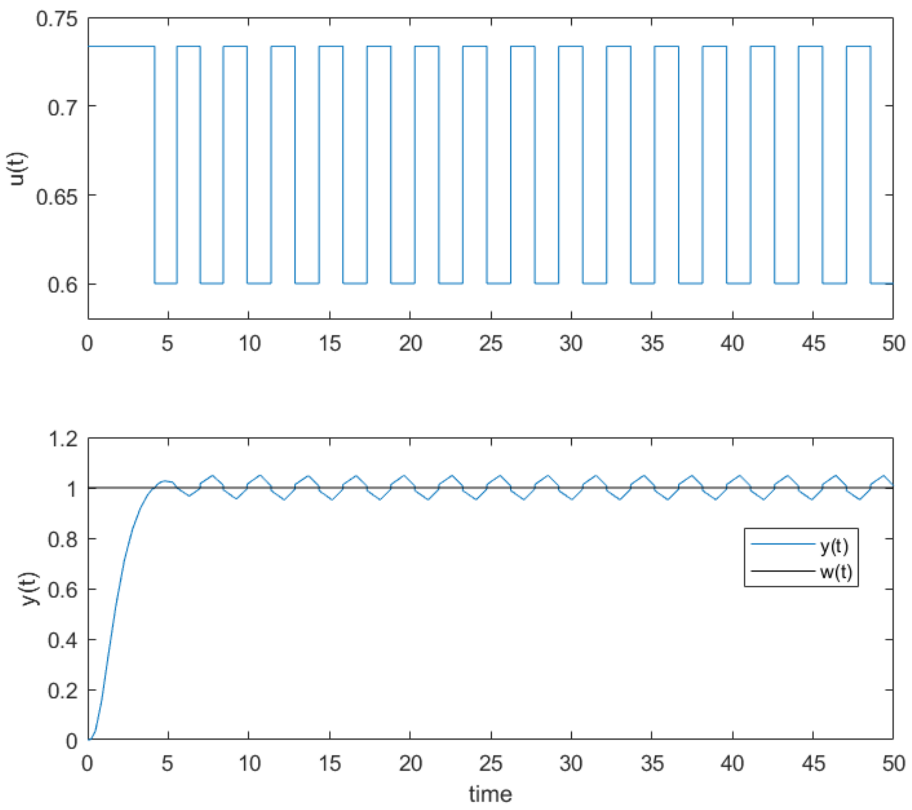

Figure 1: Figure of system inputs and outputs

Thanks to these oscillations, we have calculated the parameters T_c = 2.9800 and Z_c = 1.7061, where T_c is the time of one period of our output and Z_c is calculated from following equation:

$$Z_c = \frac{4\Delta u}{\pi \Delta y}.$$

2 PID Control

Second task was to design the PID controllers using Ziegler-Nichols Method and calculated parameters T_c and Z_c. Calculated values of these controllers are in the following table 1.

G_R	Z_R	T_I	T_D
P	0.8531		
PI	0.6825	2.3840	
PID	1.0237	1.4900	0.3725
PID – small overshoot	0.5630	1.4900	0.9933

Table 1: All PID controllers designed by using Ziegler-Nichols Method

Figure 2 shows controlled inputs for each controller and figure 3 shows controlled outputs for each controller.

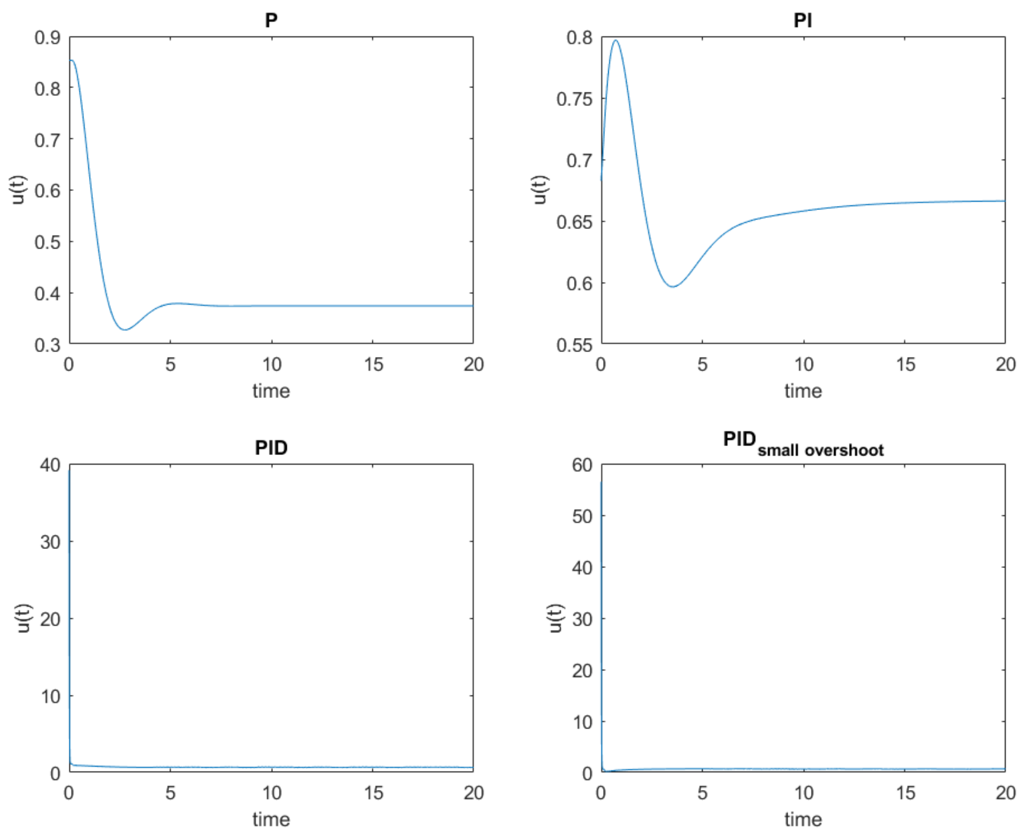

Figure 2: Figure of controlled inputs for each controller

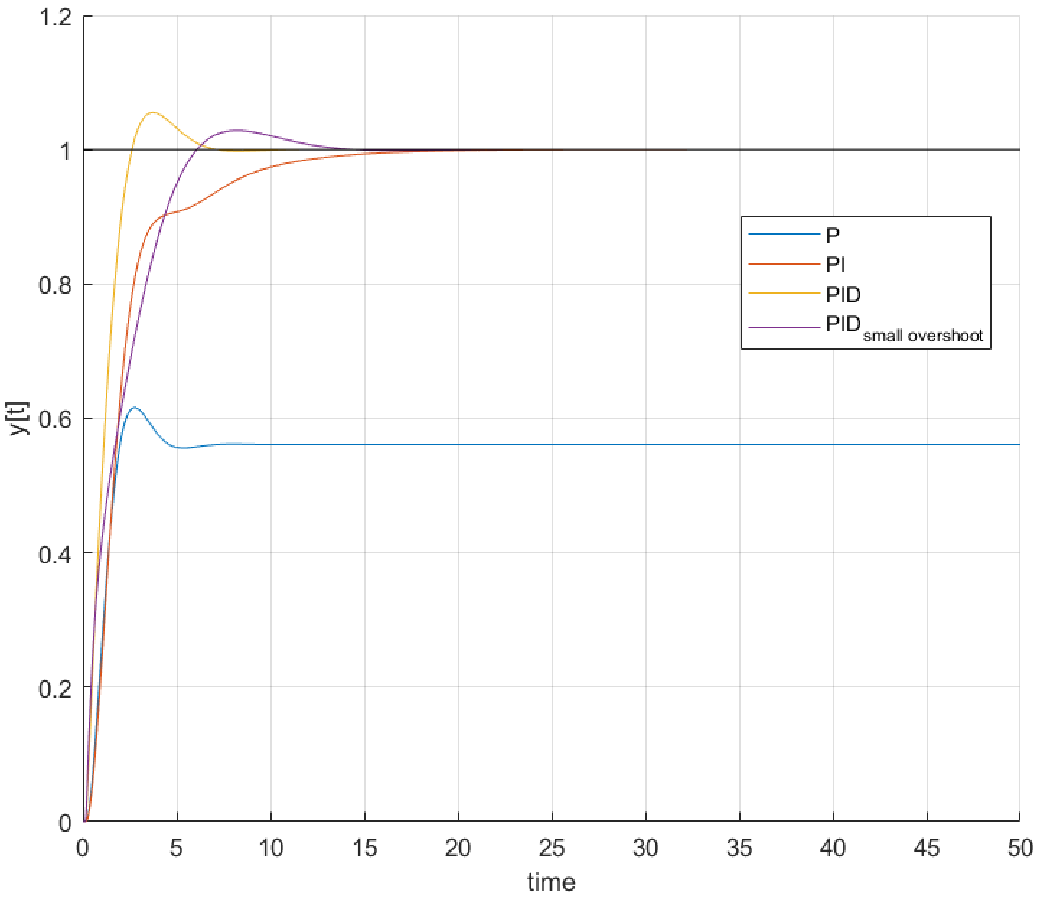

Figure 3: Figure of controlled outputs and reference for each controller

As we can see in the thirth figure, P controller is the weakest controller, because it cannot reach the setpoint. The rest of controllers reach our setpoint, thanks to their integration components. PI controller is the slowest. When we added derivative component, our settling time was shorter. In the table 2 we can see computed values of integral quality criterion ISE for each controller. Based on these values we can say that the best controller is PID. This controller is the fastest and has no much more overshoot than PID controller with small overshoot, which is the second best.

	P	**PI**	**PID**	**PID – small overshoot**
ISE	10.3467	1.2915	0.7382	1.0254

Table 2: Computed values of integral quality criterion ISE for each controller

3 Conclusion

The aim of this assignment was to designed the suitable PID controller using the relay-feedback-based auto-tuning approach. As we can see in the last figure, where we compare computed controllers, each component of controller has its role. The proportional action produces an output value that is proportional to the current error value. The integration action eliminates the steady-state error, but also brings more and larger oscillations and overshoot. When we want to have smaller overshoot, our settling time will be longer. The derivative action responds to the rate of change of the error signal and typically leads to smaller overshoot and a better damped behavior, but also to larger steady-state errors. Therefore, we must try to find the optimal solution by tuning all the components.